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INHERENT P SUPPLYING ABILITY OF ORGANICALLY MANAGED SOILS

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Inherent P Supplying Ability of
Organically Managed Soils

Project # 20080071

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(a) Abstract/Summary:

The overall objective of this study was to perform soil-based and plant-based measurements of nutrient availability on soils from organic and conventional farms to identify which measurements are best suited for each system and identify which measurements best represent the overall fertility of the soil for crop growth. Soil-based measurements of N and P availability included standard soil test measurements of pre-seeding available N and P, N and P mineralized over a 28 or 56 day period, and N and P adsorption onto PRS probes. Nitrogen and P taken up into plant tissue was also measured monthly over the growing season as a measure of the actual nutrients that were taken up by the plants. One cereal and one legume field on three organic farms and one conventional farm in the Brown, Dark Brown and Black soil zones were intensively sampled. Cereal and legume fields from a single organic and conventional farm were sampled in the Gray soil zone. Statistical relationships between the different nutrient availability measurements were evaluated to determine the best measurement of availability and to evaluate whether the organic and conventional soils functioned differently.

The inherent ability of the soils to mineralize N and P was not different between the organic and conventional soils. Organically managed soils did not mineralize more nutrients than the conventional soils as is frequently assumed to be the case. Some organically managed soils supported lower mineralization than the conventionally managed soil in the region. In general, low pre-seeding N and P values were associated with a low mineralization potential in the organically managed soils but not in the conventionally managed soils. It appears that the low pre-seeding available N and P levels in the organically managed soils are general indicators of overall low fertility. When fertility is low there simply is less N and P available in organic form to mineralize. Despite the frequently low fertility levels in the organically managed soils, cereal crop growth and nutrient uptake were closely linked to the supply of both N and P throughout the growing season. Even though they did not have inherently higher ability to mineralize nutrients, organically grown cereals obtained a larger proportion of their nutrients from mineralization than conventionally grown cereals, simply because no other source of nutrients was available to them.

Not surprisingly legumes in both systems were not dependent on mineralization for their N supply because they can fix atmospheric N. However, P supply also seemed to be somewhat independent of mineralization, particularly in the organic system possibly because of AMF associations or other unidentified mechanisms. The percentage of roots colonized by AMF was not different between legumes grown in the conventional and organic systems, but the two systems may have been dominated by different AMF species which can differ in their effectiveness.

In general, nutrient estimates made using the PRS probes correlated well with actual nutrient uptake. Correlations were very good for the cereals, but were not as good for the legumes. This adds to the evidence that other controls on P availability are functioning in legumes. PRS probe measurements from a previous season could provide information on the fertility of a field for a subsequent year.

(b) Introduction:

Microorganisms are responsible for the cycling of soil nutrients and may play a more important role in organic systems than conventional systems because of the heavy reliance on organic matter inputs in organic systems. Green manure systems, common to organic production systems, supported higher carbon mineralization rates compared to fallow-wheat and continuous wheat systems, as well as higher total bacteria numbers, ratios of bacteria to actinomycetes and numbers of filamentous fungi and nitrifiers (Biederbeck et al., 2005). Application of inorganic fertilizers in conventional systems may reduce the reliance on microorganisms for mineralizing nutrients for a growing crop.

In a Saskatchewan survey of 60 organically managed fields where soil test levels of N, P and S were measured, P was deficient in all fields measured, and N ranged from optimal to deficient levels with the majority of the fields in the marginal to deficient range (Knight et al., 2010). Sulphur was the most variable ntrient, with some fields severely deficient and others well above optimal (Knight et al., 2010). Despite the soil test levels indicating widespread P deficiency, producers report crop yields exceeding those expected based on the soil test results. There are some reports that organically bound P (i.e., P_o in organic matter) is more important in soils that are low in P (Tiessen 1995) and hence may be more important in organic systems. Organic P is not accessible for uptake directly. Only inorganic orthophosphate ions ($H_2PO_4^-$ or HPO_4^{2-}; collectively refered to as P_i) can be taken up by plant roots. Organic P must be mineralized and the P_i released before it is available for plant growth. Standard soil tests do not include a measure of mineralization potential.

Nutrient mineralization provides a more accurate measure of nutrient availability. Measurement of net nutrient mineralization involves incubating a soil over several weeks and measuring the release of the nutrient in question during the incubation period. While pre-seeding available nutrient levels might be low in organic soils, nutrients might be more easily released throughout the growing season because of the dynamic microbial comunities in these soils.

Direct measurement of nutrient uptake involves periodic sampling of plants and examination of the nutrient content in the tissue. These uptake measurements provide information on the interactions among the soil, the plants, and the microorganisms (e.g., arbuscular mycorrhizal fungi - AMF) that all function together to influence nutrient supply. Measurements of plant uptake are the end result of the plant's ability to extract nutrients from the soil, as well as the affect that microorganisms and the plants themselves have on plant available nutrient levels. Since AMF require the presence of a complementary plant species, the affect of AMF are not accounted for in mineralization measurements.

The objectives of this study were to perform soil-based and plant-based measurements of nutrient availability on soils from organic and conventional farms to identify which measurements are best suited for each system. Secondly the study should identify differences between the management systems in terms of controls on nutrient availability. Specific objectives were to:

1. Estimate P and N mineralization in a range of organically managed soils and compare to select conventionally managed soils.
2. Examine P and N uptake by legumes and cereals grown in the same soils in objective 1;
3. Quantify AMF associations in the crops measured under objective 2;
4. Assess the relationship between pre-seeding available P status, P-mineralization potential, plant P uptake, PRS-P, and AMF colonization in a range of organically managed soils and compare to select conventionally managed soils;
5. Assess the relationship between pre-seeding available N status, N- mineralization potential, PRS-N and plant N uptake in a range of organically managed soils and compare to select conventionally managed soils.

(c) Methods:

Three organically managed fields and one conventionally managed field were selected from the Brown, Dark Brown and Black soil zones. A single organically managed field was selected from the Gray soil zone along with one conventionally managed field. The smaller representation from the Gray soil zone reflects the

smaller agricultural area and was necessary to reduce sample numbers. To qualify for inclusion in the study, the farms had to have been farmed organically for at least five years with the intent of growing a cereal and a pulse in 2009. Farms in our study had been farmed between 6 and 20+ years with an average of 12 years (Table 1). All fields selected had grown a cereal crop the previous year.

Composite soil samples composed of 10 randomly selected soil cores were collected from three locations in each field prior to seeding (and fertilizer application on the conventionally managed fields). One cereal and one legume field per farm were sampled (10 cores per location). The soil cores were sampled to a 30 cm depth. Each core was divided into a 0-15 cm and a 15-30 cm sample. The 10 samples per depth per field location were combined and the combined sample returned to the lab, resulting in six soil samples per field. These samples were used for the initial characterization of the site, as well as the mineralization studies. Soils were extracted for available N [2*M* KCl (Maynard et al., 2008)], available P [modified Kelowna (Ashworth and Mrazek 1995)] and available S [0.01*M* CaCl) Tabatabai, 1982)], EC and pH [saturated paste (Rhoades 1982)] (Table 2). One legume field in the Black soil zone was ploughed under by the farmer because of poor germination and emergence, resulting in the loss of one site.

The soils collected at this initial sampling were also used in mineralization studies (Curtin and Campbell, 2008). Mineralization was assessed in both the 0-15 cm depth and 15-30 cm depth. However correlations run for the 15-30 cm depth were not significant, so this data is not presented. Furthermore, because the 0-15cm layer of soil is where most plant roots are located and the most biologically active region of the soil, it makes sense that soil and biological factors controlling nutrient availability occur predominantly in this top soil layer.

For the mineralization assays, 5 g of soil was placed in vials and wetted to field capacity. Field capacity was determined for each soil individually. The vials were capped with parafilm punctured with several small holes. This reduced evaporation without restricting gas exchange. The vials were incubated in the dark at room temperature in a high humidity chamber. Duplicate vials from each replicated treatment were sampled at day 0 (T_0), day 28 (T_{28}) and day 56 (T_{56}).

Table 1. Summary of fields included for sampling for P and N fertility indices.

Field ID	Management	Soil Zone	Cereal	Pulse	Years Organic
OB1	Organic	Brown	wheat	lentil	17
OB2	Organic	Brown	wheat	pea	10
OB2	Organic	Brown	barley	lentil	10
CB	Conventional	Brown	wheat	pea	na
ODB1	Organic	Dark Brown	wheat	pea	7
ODB2	Organic	Dark Brown	wheat	pea	18
ODB3	Organic	Dark Brown	wheat	pea	8
CDB	Conventional	Dark Brown	wheat	pea	na
OBL1	Organic	Black	barley	pea	12
OBL2	Organic	Black	wheat	pea	20
OBL3	Organic	Black	durum	pea	6
CBL	Conventional	Black	wheat	pea	na
OG1	Organic	Gray	wheat	pea	12
CG	Conventional	Gray	wheat	pea	na

na = not applicable

At each sampling period, soils in the vials were extracted and analysed for the target nutrient. Because different extractants are used for N and P these experiments were conducted separately. Mineralization was calculated as the difference between the amount of nutrient extracted at either T_{28} or T_{56} and the amount of nutrient extracted at T_0.

Producers were responsible for seeding and crop management. All farmers inoculated the legume crops with a *Rhizobium* inoculant at seeding. Conventional farmers applied fertilizers and herbicides as needed. To account for differences in row spacing among farmers, we sampled linear rows and express results per linear m. Three 1 m rows of the standing crop from the fields were sampled monthly throughout the growing season and at final harvest. The plant samples were dried and ground and digested for subsequent nutrient analyses (Thomas et al., 1967). Harvest samples were separated into grain and straw and digested separately. Nitrate, ammonium and phosphate from the digests were quantified on a SmartChem autoanalyser.

Anion PRS™ probes (Western Ag Innovations, Saskatoon, SK) were installed in three locations within each field for simultaneous measurement of N, P and S. At the organic sites, probes were installed shortly after crop emergence in June and replaced monthly in July and August. The final probes were removed prior to the final harvest. Because of fertilizer application on the conventional fields potentially saturating the probes in a 4-week incubation, probes at the conventional sites were replaced every 2 weeks instead of 4 weeks. The two 2-week measurements in a month were added together, so that the organic and conventional field measurements could be compared. In addition, measurements for all time periods were summed to give an indication of total nutrient availability over the field season. The timing of probe placement/replacement corresponded to plant sampling throughout the field season. Thus the PRS probes provided a measure of nutrient availability in the soil, and the plant digests provided a direct measure of nutrient uptake for the same time period.

The conventional farm was selected to be in close vicinity to one of the organic farms in the soil zone. These farm pairs in each soil zone were sampled in July for AMF colonization. In the Black soil zone two organic farms were sampled because the farm nearest the conventional farm had applied an AMF inoculant at seeding. Both this farm and a second farm that had not applied an inoculant were sampled for comparison. Intact root systems from five plants were dug up from three locations in each field and returned to the lab. Roots were washed, preserved and stained for AMF (Vierheilig et al., 1998). Percent colonization was scored using the line intersect method (Giovannetti and Mosse, 1980).

Statistical Analysis:

For each field (cereal and legume) three replicate measurements were obtained for all of the N and P measurements: pre-seeding available nutrient level, mineralization T_{28} and T_{56}, plant uptake for June, July, August and Final Harvest, PRS – nutrient for June, July, August and Final Harvest. Each crop type was analysed separately. Pearson correlation coefficients and the associated probability of the correlation being significant was calculated for meaningful comparisons. For each crop type, correlations were evaluated for the organic and conventional fields separately. In addition the conventional-organic farm pairs that were sampled for AMF colonization were analyzed as a subgroup. Direct comparisons between yield parameters and nutrient uptake between these paired farms were made using paired t-tests ($P<0.05$).

(d) Results and Discussion:

Pre-seeding levels of available nutrients:

Initial pre-seeding levels of available nutrients are reported for each farm (Table 2 and 3). As was expected overall, the lowest nutrient levels occurred in the Brown zone, because of a drier climate historically supporting less biomass leading to smaller organic matter inputs into these soils.

Table 2. Available soil nutrients (g kg^{-1}) in **cereal fields** sampled pre-seeding. The same soils were used for mineralization studies.

Field ID	*Sampling depth*	*NO_3-N*		*NH_4-N*		*Tot. Avail N*		*SO_4-S*		*PO_4-P*		*EC*	*pH*
		mean	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*		
OB1	0-15	10.0	2.4	3.5	1.3	13.5	2.8	3.7	0.9	9.7	3.6	0.78	6.8
	15-30	5.0	0.3	3.1	0.0	8.1	1.1	5.0	0.9	4.5	1.6	0.62	6.8
OB2	0-15	8.4	2.7	7.2	1.0	15.6	2.2	9.7	2.9	7.7	1.3	1.12	7.7
	15-30	31.5	7.6	3.0	0.1	34.5	7.7	9.9	2.6	8.1	0.9	1.44	7.7
OB3	0-15	13.7	1.9	2.9	1.1	16.6	0.8	5.0	1.2	34.9	14.0	1.13	7.6
	15-30	38.8	10.8	4.6	0.6	43.4	11.4	5.0	0.5	6.1	1.3	1.09	7.7
CB	0-15	33.7	28.7	4.4	1.1	38.1	27.6	6.3	2.0	8.7	0.8	2.25	7.8
	15-30	6.3	1.2	3.1	1.1	9.4	2.3	6.8	0.4	4.9	1.3	1.33	7.9
ODB1	0-15	19.0	2.8	2.2	0.3	21.2	2.5	21.2	2.4	10.4	27.7	1.24	6.3
	15-30	5.7	1.5	0.9	0.4	6.6	1.6	6.6	0.7	7.3	2.0	0.84	6.1
ODB2	0-15	13.7	4.1	2.9	0.4	16.6	4.5	16.5	2.4	7.5	4.4	1.15	7.7
	15-30	5.0	2.9	2.4	1.1	7.4	4.0	7.4	4.2	8.4	3.6	1.49	7.9
ODB3	0-15	14.6	3.8	5.1	0.9	19.7	4.6	19.7	0.9	8.3	1.2	1.13	7.7
	15-30	6.0	2.2	5.4	0.6	11.4	2.8	11.4	1.6	8.9	0.3	1.52	7.9
CDB	0-15	17.6	4.0	3.3	0.9	20.9	3.4	7.2	1.4	28.7	11.7	0.94	6.0
	15-30	7.6	1.1	4.8	1.2	12.4	0.4	8.7	1.1	6.4	1.6	0.78	6.8
OBL1	0-15	22.7	5.5	5.1	2.2	27.8	7.7	45.4	7.9	9.3	0.3	4.20	7.7
	15-30	10.1	1.1	12.8	14.3	22.9	13.4	64.9	10.6	4.9	0.9	2.01	8.0
OBL2	0-15	17.1	0.8	4.1	1.9	21.2	2.1	38.3	6.5	5.3	2.5	3.95	7.7
	15-30	12.8	7.3	9.4	13.5	22.1	6.3	61.2	9.5	3.3	0.7	2.38	8.0
OBL3	0-15	23.7	1.4	5.0	1.0	28.7	0.6	8.7	0.3	23.6	9.8	1.45	7.3
	15-30	15.5	3.3	3.8	1.8	19.3	3.0	8.2	1.5	11.5	3.5	1.04	7.5
CBL	0-15	10.3	2.5	4.3	1.0	14.6	3.3	192.8	83.0	35.9	14.3	2.25	6.6
	15-30	32.4	18.9	4.4	0.8	36.8	19.7	143.5	15.5	54.3	33.4	1.93	6.6
OG	0-15	16.9	2.8	6.1	1.2	23.0	4.0	12.9	4.3	15.9	13.3	0.90	6.1
	15-30	7.3	5.3	2.3	0.5	9.6	5.8	12.5	5.5	17.3	16.1	0.72	6.1
CG	0-15	9.3	4.1	7.2	0.2	16.5	4.3	18.1	4.7	13.6	1.0	1.56	5.8
	15-30	16.2	7.6	0.6	0.7	16.7	8.1	11.7	0.8	4.9	2.7	0.96	6.1

Table 3. Available soil nutrients (g kg^{-1}) in **legume fields** sampled pre-seeding. The same soils were used for mineralization studies.

Field ID	Sampling depth	*NO_3-N*		*NH_4-N*		*Tot. Avail N*		*SO_4-S*		*PO_4-P*		*EC*	*pH*
		mean	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*	*mean*	*± s.d.*		
OB1	0-15	6.7	1.3	6.4	0.5	13.1	1.6	5.6	1.5	7.4	0.3	0.70	7.53
	15-30	18.5	3.1	4.3	0.4	22.7	3.2	6.9	2.2	5.3	0.4	0.89	7.6
OB2	0-15	5.7	3.5	6.8	2.5	12.5	5.9	10.1	6.9	9.1	2.8	1.36	7.90
	15-30	26.9	5.8	3.5	0.3	30.4	5.5	7.2	3.3	8.2	0.7	1.13	7.83
OB3	0-15	5.9	1.2	3.9	0.3	9.8	1.0	4.1	1.0	4.2	0.3	1.26	8.03
	15-30	11.9	2.5	1.4	0.0	13.3	2.6	4.4	0.9	3.8	0.2	1.42	8.03
CB	0-15	14.7	14.5	4.0	0.7	18.7	14.3	7.1	1.9	15.0	6.9	1.29	7.67
	15-30	6.1	1.9	3.1	0.6	9.2	1.4	9.0	1.4	6.1	0.6	1.32	7.97
ODB1	0-15	23.1	12.3	2.7	0.5	25.8	12.2	9.5	4.0	42.6	31.4	1.36	6.43
	15-30	6.1	0.3	2.2	0.6	8.3	0.4	10.4	3.6	7.2	2.4	1.00	6.63
ODB2	0-15	11.9	11.1	3.9	0.8	15.8	11.8	8.2	4.9	11.6	10.0	1.45	7.77
	15-30	7.3	9.3	4.3	1.2	11.7	10.4	12.0	8.4	10.1	9.7	1.47	7.80
ODB3	0-15	9.8	1.9	4.7	0.8	14.5	2.2	15.0	4.7	15.7	2.7	0.85	7.50
	15-30	4.5	0.2	6.4	0.7	10.8	0.7	10.3	1.1	9.6	0.7	1.06	7.70
CDB	0-15	3.2	0.8	4.8	0.2	8.0	1.0	7.9	1.7	18.3	6.7	0.86	6.77
	15-30	6.3	3.5	4.3	1.5	10.7	2.3	9.0	2.6	6.3	2.2	0.66	7.10
OBL1	0-15	5.2	1.9	9.7	8.8	14.9	6.9	91.6	64.2	9.3	2.3	6.92	7.90
	15-30	2.4	0.1	5.0	0.7	7.4	0.6	83.9	86.4	4.4	0.3	4.45	8.07
OBL2	0-15	6.9	2.9	4.0	0.6	10.9	3.4	25.8	40.8	6.2	2.2	2.87	7.13
	15-30	5.0	2.4	2.6	0.4	7.6	2.5	84.9	108.8	3.7	0.1	6.81	7.57
OBL3*	0-15												
	15-30												
CBL	0-15	4.1	3.0	6.2	4.4	10.3	7.0	24.6	5.7	19.2	10.3	1.33	5.13
	15-30	13.4	9.1	3.1	0.7	16.5	9.8	20.3	3.4	5.4	1.3	0.86	6.07
OG	0-15	23.3	8.7	5.7	2.2	28.9	10.8	21.4	8.2	11.2	7.8	1.24	6.80
	15-30	7.2	3.7	3.3	0.4	10.6	4.0	12.2	3.7	6.0	2.8	0.73	6.10
CG	0-15	5.2	1.8	4.8	0.9	9.9	2.7	9.9	3.6	10.3	1.7	0.80	6.37
	15-30	9.7	4.3	2.0	0.5	11.7	4.5	12.0	6.8	3.2	0.1	0.84	7.10

***field ploughed under by farmer**

Fields showed a similar range of available nutrient values to those reported previously (Knight et al., 2010). Available N ranged from 8 g kg^{-1} to 38 g kg^{-1} with median values around 15 g kg^{-1}. Available P ranged from about 3 to 42 with a median value of about 10 g kg^{-1}. Sulphur was the most variable ranging from less than 4 to 91 g kg^{-1}. One of the farms in the Black soil zone had elevated EC levels corresponding to the high sulphur amounts.

Nitrogen availability indices:

Because fertilization recommendations are typically made based on spring soil sampling for available nutrients, the various N availability indices were initially compared to pre-seeding inorganic N measurements (Table 4). For the conventionally managed cereal fields inorganic N was weakly, negatively correlated with the 56-day mineralization of N. This means that when pre-seeding N was high, less N was mineralized over the 56-day incubation, probably because of feedback mechanisms. If pre-seeding N is high, there is not a need for N to be mineralized. In contrast, the correlation between inorganic N and mineralization in the organic fields was significant only for the 28-day incubation and the correlation was positive. The positive relationship probably is indicative of the total N status of the organic soils; those with low N having less N to be mineralized. The different relationships for the organic and conventional soils indicate an inherent difference between the microbial community mineralizing N and/or the controls over mineralization.

There was no difference between the 28-day mineralization potential of the paired organic and conventional soils in the Brown and Gray soils zones (Table 5). The conventional/organic farm pairs were used for these direct comparisons to avoid over representation of the organic farms. In contrast to the common perception that organic soils have higher mineralization potentials, in the Black soil zone the conventionally managed soil had approximately 2-3X the mineralization potential of the organic soil. Only soils from the Dark Brown soil zone had higher mineralization potentials in the organically managed compared to conventionally managed soil. Averaged over all of the soil zones N mineralization was the same between organic and conventional management.

Table 4. Pearson correlation coefficients and statistical significance between soil test pre-seeding inorganic N levels and select **nitrogen** indices measured in **cereal** fields. Correlations are presented for the organic and conventional fields individually. Significant correlations are bolded (*P*<.05).

Nitrogen indices compared	Organic		Conventional	
	r	*P*	*r*	*P*
Avail N[1] vs N T_{28}[2]	**.418**	**0.022**	-.225	.482
Avail N vs N T_{56}[3]	.052	0.784	**-.582**	**.047**
Avail N vs total yield[4]	**.504**	**0.004**	-.582	.100
Avail N vs grain yield[4]	.276	0.140	-.623	.073
Avail N vs total N uptake[4]	**.513**	**0.004**	-.608	.082
Avail N vs grain N uptake[4]	.420	0.230	-.555	.121
Avail N vs total PRS N[5]	**.659**	**0.000**	-.545	.067
N T_{28} vs total N uptake	.320	.090	.593	.093
NT_{56} vs total N uptake	.169	.382	.545	.130

[1] Avail N = KCl extracted NO_3 + NH_4 measured pre-seeding

[2]N T_{28} = KCl extracted NO_3 + NH_4 mineralized after 28 day incubation

[3]N T_{56} = = KCl extracted NO_3 + NH_4 mineralized after 56 day incubation

[4]Total yield, grain yield and N uptake are based on a 1 m rows to account for differences among row widths

[5]Total PRS N = total cumulative PRS measured N over the growing season

Table 5. Pairwise comparisons for **nitrogen** availability indices, AMF colonization and yields of **cereals** grown on organic and conventionally managed fields.

Soil Zone	Farm pair ID	-------Avail N-------		-------T $_{28}$ N-------		----N uptake----		---N_{grain}:N_{straw}---	
		Organic	**Conv.**	**Organic**	**Conv.**	**Organic**	**Conv.**	**Organic**	**Conv.**
Brown	OB3/CB	16.6b*	38.1a	40.3	35.8	303b	1464a	3.0b	8.4a
Dk Br	ODB1/CDB	2.2b	20.9a	57.1a	36.8b	954b	1744a	4.7a	3.5b
Black	OB1/CB	27.8a	14.6c	49.8b	98.0a	420b	2809a	2.9	3.0
	OB2**/CB	21.2	14.6	25.9b	98.0a	383b	2809a	4.6a	3.0b
Gray	OG/CG	23.0a	16.5b	55.1	51.4	643b	2729a	5.2a	2.7b
Mean		*10.3b*	*21.0a*	*57.1*	*55.5*	*674b*	*1751a*	*4.2*	*4.4*

Soil Zone	Farm pair ID	-------AMF (%)-------		---Grain Yield---		---Total Yield---	
		Organic	**Conv.**	**Organic**	**Conv.**	**Organic**	**Conv.**
Brown	OB3/CB	12.0b	43.0a	18.3	61.0	31.2	125.8
Dk Br	ODB1/CDB	18.0	25.3	23.4	56.2	79.2	135
Black	OB1/CB	32.3	21.7	20.2	92.7	47.9	244.2
	OB2/CB	33.3	21.7	14.8	92.7	36.5	244.2
Gray	OG/CG	36.7	27.3	23.0	64.9	60.5	150.1
Mean		*26.5*	*27.5*	*24.9b*	*54.7a*	*63.5b*	*130a*

*pairwise comparison of organic and conventional fields within a soil zone are significant if followed by different letters (t-test; *P*<.0%)

** farmer applied AMF inoculant

Mineralization is essentially the decomposition of organic matter in the soil driven by microorganisms. The microorganisms consume the organic matter for energy, releasing inorganic N in the process. If the microorganisms are deficient in N for their own metabolism they will immobilize N in their biomass and no inorganic N will be released. Although in the field these conventionally managed soils would have received fertilizer N that would alleviate any N deficiency for the microorganisms, these soils were collected prior to fertilization. These mineralization assays reflect the inherent potential of the soil, not the realized potential in the field. Clearly at least some of the microorganisms responsible for mineralization are abundant in conventionally managed soils. However, the particular species of organism or relative abundance of organisms could differ between organic and conventional soils.

Total cereal biomass yield from the organic fields was correlated with pre-seeding available N status (Table 4). Fields with low pre-seeding N yielded lower than those with high pre-seeding N. The relationship demonstrates the importance of the inherent soil N in crop production in organic systems. That the same relationship did not hold for grain yield reflects the preferential transport of N into grain production. Even under N deficient conditions N is preferentially used for grain production instead of straw production. An examination of the ratio between N in the grain and N in the straw (Table 5) between the paired conventional and organic farms indicates that except in the Brown soil zone, N in the grain in the organically grown crops represented a higher percentage of total N than N in the grain of conventionally grown cereals crops.

In the organic cereal crops pre-seeding N levels also were correlated with total N uptake as well as cumulative PRS-N measured over the entire growing season. Nitrogen mineralized over the season is more important for total biomass production and N uptake in organic crops than conventionally grown crops because of the application of N fertilizer in conventional production. Even though the rates of mineralization are not consistently different between the systems, mineralized N constitutes a larger proportion of the N taken up by the crop. Not surprisingly, the conventionally managed fields did not show the same relationship between yield, N uptake and inorganic N level, because

the addition of fertilizer N uncoupled the link to pre-seeding N levels and the reliance on mineralized N.

Cereal grain yield and total biomass yield from conventional management averaged over the soil zones was approximately double the grain yield obtained from organic management (Table 5). Nitrogen uptake was 2.5X higher. The largest differences between yields and N uptake between the two systems occurred in the more inherently fertile Black and Gray soil zones, with the smallest differences occurring in the Brown and Dark Brown soil zones. It is clear that N is limiting yield in the organic systems. In the Black and Gray soil zones where water is typically less limiting than in the Brown and Dark Brown soil zones, the differences between the management systems are even more pronounced.

As was the case with the cereal crops, in the organic legume crops correlations existed between pre-seeding inorganic N and the other soil-based N availability indices, in particular the 28 day mineralization assay and total PRS-N (Table 6). Although there are exceptions, the shorter mineralization assay typically was a more reliable assay than the longer assay and most likely to correlate with other N measurements. The longer (56-day) mineralization assay was more variable. As was the situation with the cereal fields, the conventionally managed legume field soils showed a negative relationship between inorganic N and mineralization, and the organic soils a positive relationship between inorganic N and mineralization, reflecting a difference in the functioning of the microbial populations between the two soils. No crops had been grown on these soils yet so an inherent difference between the cereal and legume soils was not expected for mineralization. Once again, it appears that in the organic soils, the total N status of the soil is probably driving mineralization, with low N soils supporting low N mineralization simply because less organic N is in the soil to be mineralized. In the conventional soils the inorganic N is the driving factor with low inorganic N levels triggering a higher mineralization potential than high inorganic N levels.

Table 6. Pearson correlation coefficients and statistical significance between select **nitrogen** indices measured throughout the growing season measured in **legume** fields. Correlations are presented for the organic and conventional fields individually. Significant correlations are bolded (P<.05).

Nitrogen indices compared	Organic		Conventional	
	r	*P*	*r*	*P*
Avail N[1] vs N T_{28}[2]	**.623**	**.001**	-.064	.844
Avail N vs N T_{56}[3]	.197	.326	**-.763**	**.004**
Avail N vs total yield[4]	.042	.836	-.308	.420
Avail N vs grain yield[4]	.082	.686	-.259	.501
Avail N vs total N uptake[4]	.179	.371	-.258	.503
Avail N vs grain N uptake[4]	.151	.451	-.237	.540
Avail N vs total PRS N[5]	**.815**	**.000**	-.346	.271
N T_{28} vs total N uptake	.165	.411	**.731**	**.025**
NT_{56} vs total N uptake	-.012	.952	.405	.280

[1] Avail N = KCl extracted NO_3 + NH_4 measured pre-seeding

[2]N T_{28} = KCl extracted NO_3 + NH_4 mineralized after 28 day incubation

[3]N T_{56} = = KCl extracted NO_3 + NH_4 mineralized after 56 day incubation

[4]Total yield, grain yield and N uptake are based on a 1 m rows to account for differences among seeding widths

[5]Total PRS N = total cumulative PRS measured N over the growing season

Mineralization potentials were generally slightly higher in the conventionally managed soils than the organically managed soils, with the exception of the Dark Brown soil zone (Table 7) and are probably due to higher organic matter inputs from residues. Because the conventional crops produce more biomass than the organic counterparts, they produce more residue as substrates for mineralization.

Unlike the cereal crop fields, none of the plant-based indices for the legumes were correlated with pre-seeding inorganic N levels. Because legumes have the ability to fix N from the atmosphere, this decoupling of plant growth and N uptake from the soil is not unexpected and occurred in both the organic and conventional management systems. As long as a legume crop is well nodulated and actively fixing N, the N status of the soil should not be a limiting factor to growth and productivity.

Both plant N uptake and PRS-N give indications of N availability during the growing season that soil inorganic N measurements do not. Particularly in the organic system these two indices are relatively well correlated in the cereal crops throughout the growing season (Fig. 1 and Table 8). Only at the final harvest were the indices significantly correlated in the conventional system. The stronger correlation in the organic cereal system compared to the conventional cereal system indicates that plant N uptake and nutrient supply are more closely coupled in the organic system. In the conventional system, N is available in abundant supply throughout the growing season. Not surprisingly, the legume system did not follow the same pattern as the cereals in either management system (Fig. 2 and Table 8). The legume crop does not rely exclusively on the soil for its N supply with biological N fixation supplying some of the N for growth and seed production.

The protocols for measuring tissue N contents (and other nutrients) are extremely laborious, expensive, and use dangerous, toxic chemicals in their analyses. PRS probes on the other hand are much easier to implement. However, as they are used in this study, both measurements give an indication of nutrient availability in the season the crop is grown, but are not predictive tools for influencing management decisions prior to the growing season. We investigated if a PRS-N measurement made at various points throughout the season was correlated with final grain yields

(Table 9) with the idea that if a deficiency could be identified early in the season it might still be possible to provide some sort of corrective management. In the organic cereals there were only weak correlations between PRS-N and grain yield and the strongest correlation occurred between the final PRS-N measurements and grain yield, when it is too late to influence management. However, in the organic system where N uptake and PRS-N are relatively well correlated (Table 8) information from a previous year should help with management decisions in an upcoming year since readily available N-fertilizers are not applied.

Table 7. Pairwise comparisons for **nitrogen** availability indices, AMF colonization and yields of **legumes** grown on organically and conventionally managed fields.

Soil Zone	Farm pair ID	Avail N		T_{28} N		N uptake		N_{grain}:N_{straw}	
		Organic	Conv.	Organic	Conv.	Organic	Conv.	Organic	Conv.
Brown	OB3/CB	9.8b*	18.7a	30.9	40.3	641	526	2.8a	2.2b
Dk Br	ODB1/CDB	25.8a	8.0b	56.4a	38.8b	1187	1729	3.6a	3.1b
Black	OB1/CB	14.9	10.3	40.7b	75.2a	2209	2886	2.5	3.1
	OB2**/CB	10.9	10.3	32.8b	75.2a	577b	2886a	3.1	3.1
Gray	OG/CG	28.9a	9.9b	46.6	51.9	1760	1771	2.8b	5.3a
Average		*18.0*	*11.4*	*40.2*	*51.5*	*1029*	*1328*	*3.0*	*3.4*

Soil Zone	Farm pair ID	AMF (%)		Grain Yield		Total Yield	
		Organic	Conv.	Organic	Conv.	Organic	Conv.
Brown	OB3/CB	45.3	55.0	18.6a	5.5b	36.8	23.8
Dk Br	ODB1/CDB	20.3b	60.7a	29.2	36.2	55.0	82.4
Black	OB1/CB	52.7a	37.7b	37.7b	62.5a	94.2	127.0
	OB2*/CB	50.7a	37.7b	12.9b	62.5a	27.6b	127.0a
Gray	OG/CG	49.7	45.3	37.4	40.5	71.0	96.5
Average		*43.3*	*49.7*	*20.1*	*30.4*	*46.2*	*61.8*

*pairwise comparison of organic and conventional fields within a soil zone are significant if followed by different letters (t-test; *P*<.05)

** farmer applied AMF inoculant

Table 8. Pearson correlation coefficients (*r*) and statistical significance (*P*) between nutrient uptake in plant tissues and PRS–estimated levels of nutrients throughout the growing season. PRS values are cumulative values to the month reported (e.g. July PRS-N is for the June to July period; August PRS-N is for June through August). Correlations are reported for organic and conventional fields. Bolded values indicate statistical significance ($P < 0.05$).

Field	Parameters compared	Organic		Conventional		Related Figure
		r	*P*	*r*	*P*	
Cereal	July N uptake vs July PRS-N	**.483**	**.008**	-.330	.294	1
	Aug N uptake vs Aug PRS-N	**.448**	**.028**	.264	.408	1
	Harv N uptake vs Harv PRS-N	**.794**	**.000**	**.782**	**.013**	1
Legume	July N uptake vs July PRS-N	.223	.264	-.213	.506	2
	Aug N uptake vs Aug PRS-N	-.202	.379	.153	.635	2
	Harv N uptake vs Harv PRS-N	-.016	.936	.330	.385	2
Cereal	July P uptake vs July PRS-P	**.764**	**.000**	**.736**	**.006**	3
	Aug P uptake vs Aug PRS-P	**.590**	**.002**	**.801**	**.002**	3
	Harv P uptake vs Harv PRS-P	**.626**	**.000**	**.672**	**.047**	3
Legume	July P uptake vs July PRS-P	.327	.096	.351	.264	4
	Aug P uptake vs Aug PRS-P	.141	.543	.006	.984	4
	Harv P uptake vs Harv PRS-P	-.131	.514	.243	.528	4

Table 9. Pearson correlation coefficients (*r*) and statistical significance (*P*) between PRS–estimated levels of nutrients throughout the growing season and grain yield. PRS values are cumulative values to the month reported (e.g. July PRS-N is for the June to July period; August PRS-N is for June through August). Correlations are reported for organic and conventional fields individually. Bolded values indicate statistical significance ($P < 0.05$).

Field	Parameters compared	Organic		Conventional	
		r	*P*	*r*	*P*
Cereal	July PRS-N vs grain yld	.365	.052	.092	.815
	Aug PRS-N vs grain yld	.297	.111	.650	.058
	Harv PRS-N vs grain yld	**.485**	**.007**	.454	.220
Legume	July PRS-N vs grain yld	-.093	.643	.003	.994
	Aug PRS-N vs grain yld	.183	.360	.239	.535
	Harv PRS-N vs grain yld	-.103	.610	.561	.116

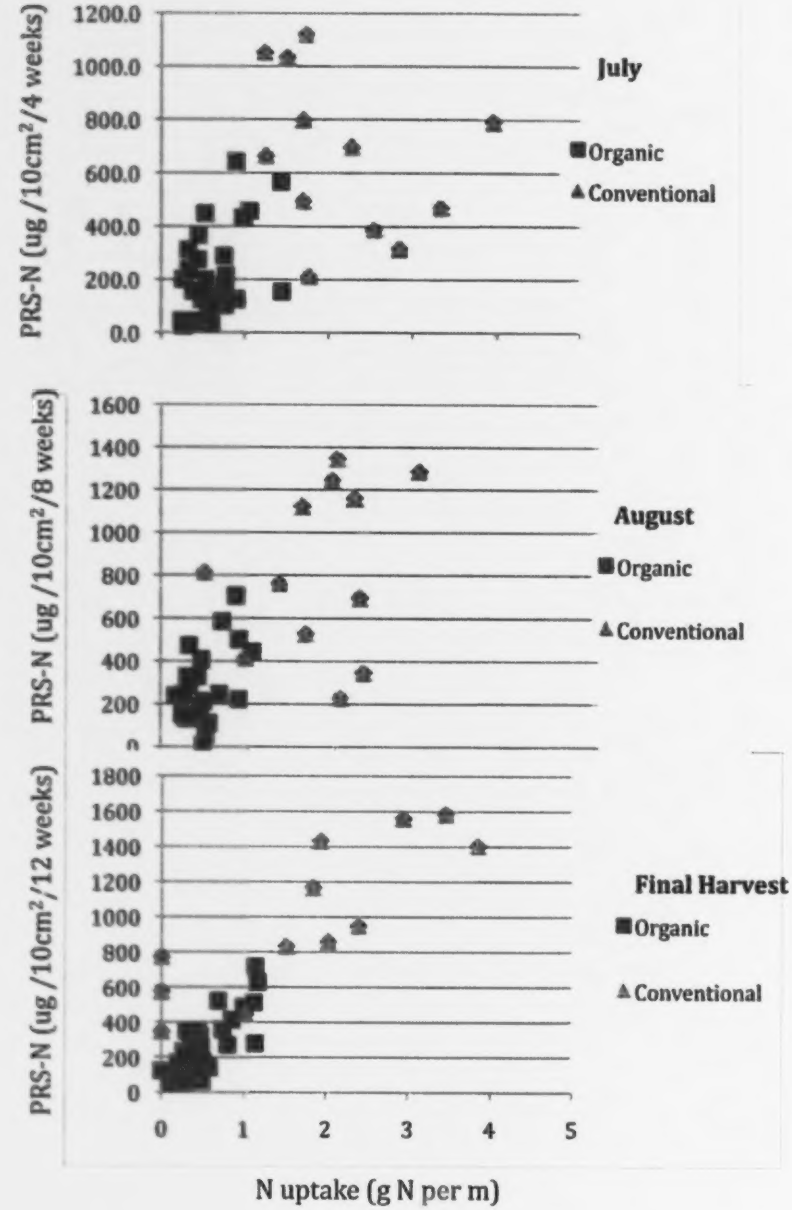

Fig 1. Correlation between N uptake and PRS-N in cereal crops under organic and conventional management. N uptake is expressed as uptake per linear m of crop to account for differences in row spacing. Correlation coefficients and corresponding probability levels are reported in Table 8.

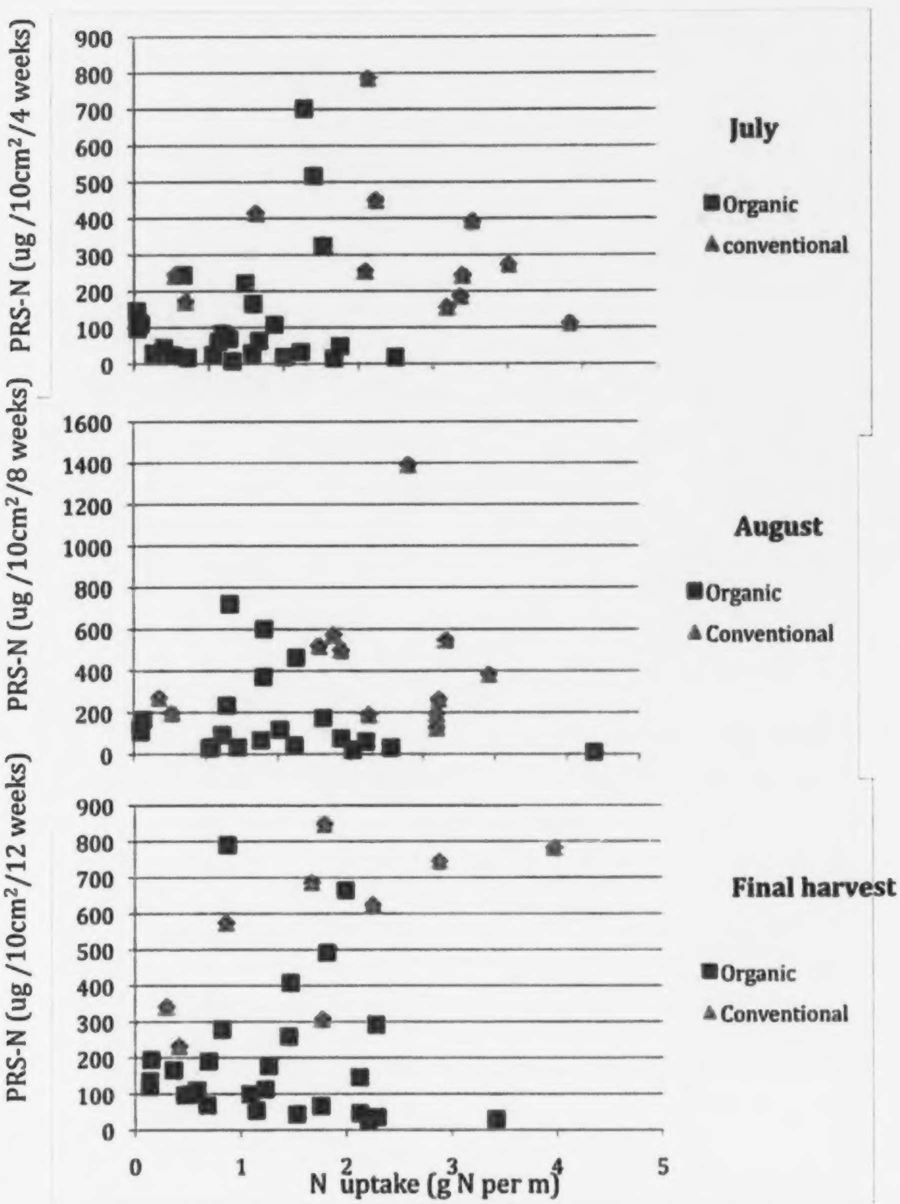

Fig 2. Correlation between N uptake and PRS-N **in legume** crops under organic and conventional management. N uptake is expressed as uptake per linear m of crop to account for differences in row spacing. Correlation coefficients and corresponding probability levels are reported in Table 8.

Phosphorus Availability Indices:

Surprisingly, pre-seeding inorganic P levels were more strongly correlated with soil and cereal plant availability indices on the conventionally managed soils than the organically managed soils (Tables 10 and 11). The shorter–term mineralization (P T_{28}) studies were more strongly correlated with pre-seeding P in both management systems than the longer-term mineralization test. In the conventional, cereal system (Table 10) pre-seeding inorganic P was correlated with total yield, grain yield, total P uptake and grain P uptake whereas only total P uptake and grain P uptake were related to pre-seeding inorganic P level in the organic system. Pre-seeding available P was not related to yield parameters in the organic system. In the conventional system, pre-seeding P levels are used to determine fertilizer application rates: at least in theory, low inorganic P levels lead to higher rate of P applied. The relationship in this system possibly reflects the plant growth response to differential fertilization. Furthermore, in the organic system, N might have been the most limiting nutrient to the extent that crops did not respond to the supply of other nutrients.

Among the cereal field farm pairs (Table 11), except in the Brown and Gray soil zones pre-seeding P levels were considerably higher in the conventional soils than the organic soils. In the legume field farm pairs (Table 13), the available P levels were more similar between the conventional and organic farms and are an indication of the variability and the affect of past management on nutrient supply. In the cereal crops P uptake was as much as 16 times greater in the conventional soils than the organic soils with the largest difference between the two systems occurring in the Black soil zone. It may be that the conventional farm selected in the Black soil zone is not representative of the soil zone and had exceptional yields (Table 5) and nutrient extraction (Table 5 and 11), but in stark contrast, the organic farms in this zone were very low yielding, and had very low P mineralization contributing to low P uptake by the cereals. At both organic farms in the Black zone, P mineralization values were negative indicating that P was immobilized rather than mineralized over the incubation period.

Table 10. Pearson correlation coefficients and statistical significance between soil test pre-seeding available P levels and select **phosphorus** indices measured in **cereal** fields. Correlations are presented for the organic and conventional fields individually. Bolded values are statistically significant (P<.05).

Phosphorus indices compared	Organic		Conventional	
	r	*P*	*r*	*P*
Avail P[1] vs P T_{28}[2]	**.562**	**.001**	**.969**	**.000**
Avail P vs P T_{56}[3]	-.299	.109	**.836**	**.001**
Avail P vs total yield[4]	.329	.076	**.799**	**.010**
Avail P vs grain yield[4]	.172	.363	**.672**	**.048**
Avail P vs total P uptake[4]	**.643**	**.000**	**.722**	**.028**
Avail P vs grain P uptake[4]	**.481**	**.008**	**.716**	**.030**
Avail P vs total PRS P[5]	**.967**	**.000**	**.975**	**.000**
P T_{28} vs total P uptake	**.480**	**.008**	**.811**	**.008**
PT_{56} vs total P uptake	**.381**	**.041**	**.686**	**.041**
pH vs total P uptake	**-.514**	**.004**	-.287	.454
pH vs T_{28}	**-.551**	**.002**	.078	.809

[1] Avail P = Kelowna extracted PO_4 measured pre-seeding
[2]P T_{28} = Kelowna extracted PO_4 after 28 day incubation
[3]P T_{56} = Kelowna extracted PO_4 after 56 day incubation
[4]Total yield, grain yield and P uptake are based on a 1 m rows to account for differences among row spacing
[5]Total PRS P = total cumulative PRS measured P over the growing season

Table 11. Pairwise comparisons for **phosphorus** availability indices of **cereals** grown on organic and conventionally managed fields.

Soil Zone	**Farm pair ID**	**-----Avail. P-----**		**------T_{28}P-----**		**----P uptake----**	
		Organic	**Conv.**	**Organic**	**Conv.**	**Organic**	**Conv.**
Brown	OB3/CB	6.1	8.7	17.3a	-.3b	89b	269a
Dk Br	ODB1/CDB	10.4b*	28.7a	13.2	7.9	226	329
Black	OB1/CB	9.3b	35.9a	-.4b	34.9a	65b	692a
	OB2**/CB	5.3b	35.9a	-.5b	34.9a	42b	692a
Gray	OG/CG	15.9	13.6	3.2	7.2	146b	374a
Average		*9.4b*	*21.7a*	*8.2*	*12.5*	*142b*	*334a*

*pairwise comparison of organic and conventional fields within a soil zone are significant if followed by different letters (t-test; $P<.05$)

** farmer applied AMF inoculant

Table 12. Pearson correlation coefficients and statistical significance between select **phosphorus** indices measured throughout the growing season measured in **legume** fields. Correlations are presented for the organic and conventional fields individually. Bolded values are statistically significant (P<.05).

Phosphorus indices compared	Organic		Conventional	
	r	*P*	*r*	*P*
Avail P[1] vs P T_{28}[2]	.202	.311	**.632**	**.027**
Avail P vs P T_{56}[3]	-.330	.093	.299	.346
Avail P vs total yield[4]	-.004	.982	-.120	.758
Avail P vs grain yield[4]	.060	.764	-.184	.635
Avail P vs total P uptake[4]	.352	.072	-.279	.468
Avail P vs grain P uptake[4]	**.418**	**.030**	-.298	.436
Avail P vs total PRS P[5]	**.973**	**.000**	**.663**	**.019**
P T_{28} vs total P uptake	-.214	.285	.289	.450
PT_{56} vs total P uptake	-.352	.072	**-.720**	**.029**
pH vs total P uptake	-.137	.494	-.642	.063
pH vs T_{28}	-.064	.751	**-.729**	**.007**

[1]Avail P = Kelowna extracted PO_4 measured pre-seeding
[2]P T_{28} = Kelowna extracted PO_4 after 28 day incubation
[3]P T_{56} = Kelowna extracted PO_4 after 56 day incubation
[4]Total yield, grain yield and P uptake are based on a 1 m rows to account for differences among row spacing
[5]Total PRS P = total cumulative PRS measured P over the growing season

Table 13. Pairwise comparisons for **phosphorus** availability indices, AMF colonization and yields of **legumes** grown on organic and conventionally managed fields.

Soil Zone	Farm pair ID	-----Avail. P------		-------T_{28}P--------		-----P uptake-----	
		Organic	**Conv.**	**Organic**	**Conv.**	**Organic**	**Conv.**
Brown	OB3/CB	4.4	7.1	11.7a	1.46b	62	65
Dk Br	ODB1/CDB	9.5	7.9	10.2	5.9	140	213
Black	OB1/CB	9.3b*	19.2a	-2.1b	10.8a	141b	312a
	OB2**/CB	6.2b	19.2a	-.96b	10.8a	48b	312a
Gray	OG/CG	11.2	10.3	3.9	5.8	169	262
Average		*8.1*	*11.1*	*5.2*	*6.0*	*85b*	*160a*

*pairwise comparison of organic and conventional fields within a soil zone are significant if followed by different letters (t-test; $P<.05$)

**farmer applied AMF inoculant

Because of the inherently high soil organic matter levels in soils in the Black soil zone, it is very surprising that organic crops in these soils were the poorest at extracting nutrients and growing crops. Interestingly these cereal crops had the highest AMF infection rates but this did not overcome the nutrient deficiencies.

As was the case with N measurements, the relationship between pre-seeding available P and plant indices did not persist for the legumes (Table 12). However, unlike N where biological N fixation removed some of the reliance on the soil for supplying N, legumes rely exclusively on the soil (or added P sources) for P fertility. Pre-seeding available P was weakly correlated with grain P in the organic system only.

Arbuscular mycorrhizal fungi associations can enhance nutrient uptake, and specifically P by expanding the volume of soil accessed for P uptake, as well as active transport of P into plant roots. AMF typically form under low P conditions and are inhibited by amendments with high P contents (e.g., manures, fertilizer P etc.). For this reason AMF associations are thought to be more important in organic systems than conventional systems. Results from the paired conventional/organic fields in each soil zone indicate that this is not always the case (Tables 5 and 7). In the Brown and Dark Brown soil zones the conventional crops (both legumes and cereals) had higher percentage colonization than organic crops. In the Black and Gray zones the reverse was true. Percent colonization does not give any indication on the effectiveness of the association. It may be that different species of AMF are responsible for colonization in the two systems and that the species differ in their ability to enhance P uptake. The cereal and legume crop in the Black soil zone that were inoculated with AMF did not have a higher degree of colonization than the other organic farm in the soil zone nor was P-uptake enhanced in the inoculated crops. In the cereals, P uptake was not affected by inoculation (Table 11) but in the legume, inoculation appears to have reduced P uptake (Table 13). Indeed, *Glomus intraradices*, the species of AMF in commercial inoculants had the least effect on plant growth and nutrient uptake of three AMF species evaluated (Adeleke, 2010). In that study, inoculation with *G. intraradices* was not different from an uninoculated control. It may be that the introduced AMF species outcompeted the native AMF species but was not as effective as the native species in stimulating P uptake.

It is interesting to note that overall legume roots experienced higher colonization percentages (Table 7) than the cereals (Table 5). Previous studies examining pulses as green manure crops reported that lentil and pea were as effective at extracting P from the soil as were crops like buckwheat and oilseed radish that are grown specifically for their P extracting capabilities (Knight and Shirtliffe, 2006). It appears that at least part of the reason pulses are very good at extracting soil P is their ability to associate with AMF. This enhanced ability to extract soil P may have impacted the expected relationship between inorganic P and P uptake and yield. Rather than AMF colonization being correlated with inorganic P levels, it is more likely that the associations form in response to some threshold level of available P.

The significant correlation between pH and total P uptake by the cereals indicates a linkage between soil conditions and P availability in the organic system which is absent in the conventional system (Table 10). In the pH range of these soils (6.0-8.0), lower soil pH results in more available P in solution, which in turn is available for uptake into the growing crop. When readily available fertilizer is present, soil pH plays a much lesser role in P supply to the plant since pH does not control availability. The lack of the same relationship occurring in the legumes indicates that some other process (possibly AMF or root exudates) are involved in controlling P availability more than the pH driven dissolution of mineral forms of P.

The strongest relationship in both the organic and conventional soils for both crop types occurred between inorganic P in the soil and total, cumulative P measured with the PRS probes. In all cases soils with low pre-seeding levels of available P released low amounts of P over the season. Relatively strong correlations existed between P uptake by the cereals and PRS-P measured monthly over the growing season (Fig 3. and Table 8) in both the organic and conventional systems. No relationships existed for the legumes (Fig. 4 and Table 8). PRS anion probes adsorb plant available forms of anions from solution over a specified time period.

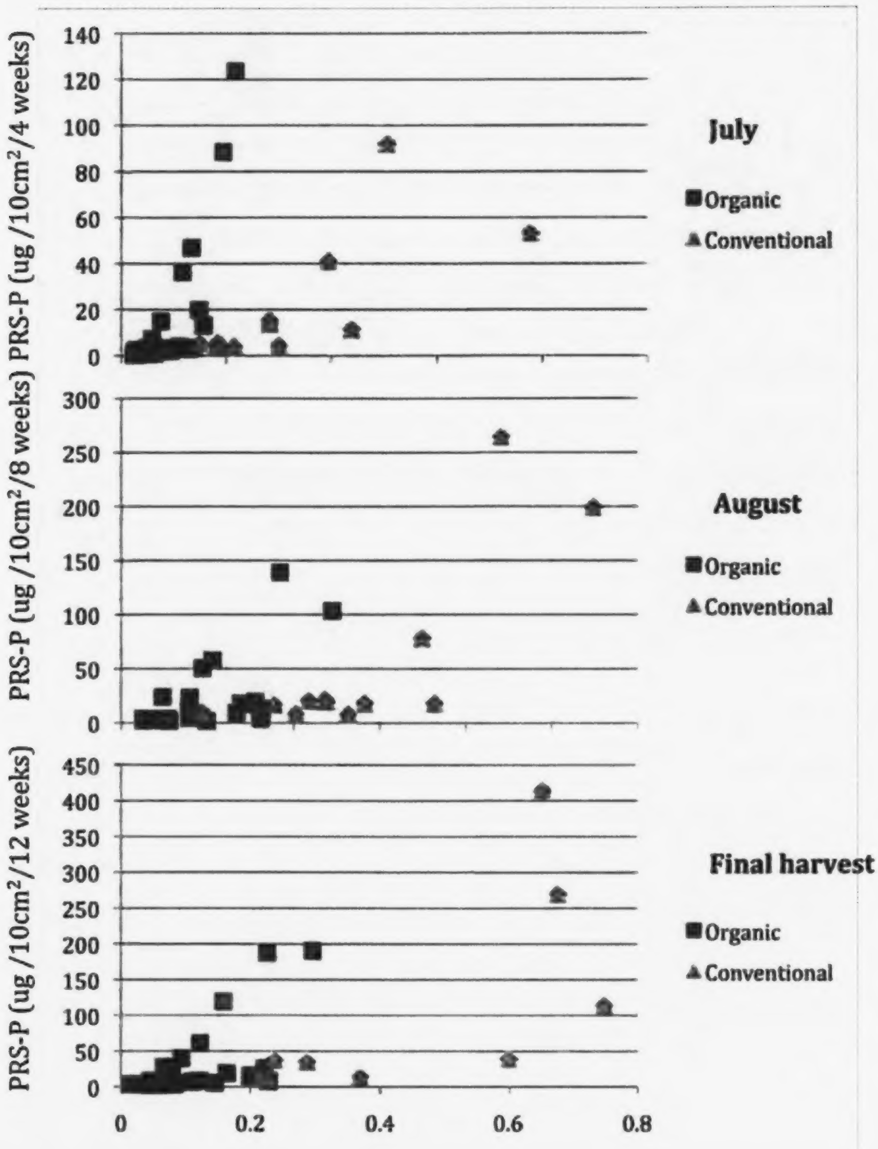

Fig 3. Correlation between P uptake and PRS-P **in cereal** crops under organic and conventional management. N uptake is expressed as uptake per linear m of crop to account for differences in row spacing. Correlation coefficients and corresponding probability levels are reported in Table 8.

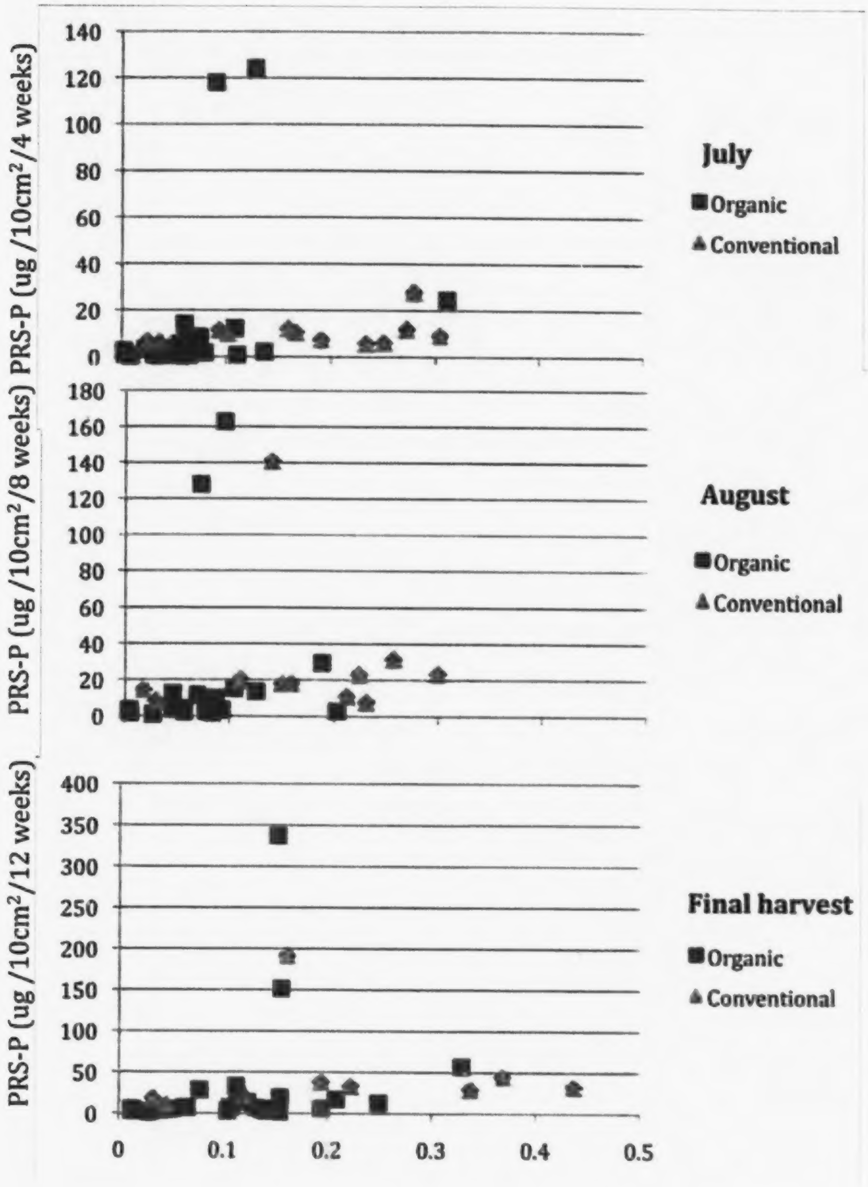

Fig 4. Correlation between P uptake and PRS-P **in legume** crops under organic and conventional management. P uptake is expressed as uptake per linear m of crop to account for differences in row spacing. Correlation coefficients and corresponding probability levels are reported in Table 8.

The lack of relationship indicates some mechanism functioning in legumes, that is interfering with the measurement of soil solution nutrients or simply missing measuring a source of nutrients available to the plants. Strong AMF associations could enhance uptake efficiency to an extent that the nutrients mobilized by the associations are not captured on the anion surfaces. Similarly, root exudates excreted into the rhizosphere of plant roots can solubilize nutrients (especially P) for plant uptake. The localization in the rhizosphere means that plants have immediate access to these nutrients for uptake and could possibly preclude the adsorption of the nutrients on the PRS probes.

Correlations between PRS-P estimates made throughout the growing season and final grain yield were generally not significant (Table 14). There was only a weak relationship between July measured PRS-P and grain yield in the conventional system.

Table 14. Pearson correlation coefficients (r) and statistical significance (P) between **phosphorus** uptake in plant tissues and PRS–estimated levels of nutrients throughout the growing season. PRS values are cumulative values to the month reported (e.g. July PRS-N is for the June to July period; August PRS-N is for June through August). Correlations are reported for organic and conventional fields individually. Bolded values indicate statistical significance ($P < 0.05$).

Field	Parameters compared	Organic		Conventional	
		r	P	r	P
Cereal	July PRS-P vs grain yld	.154	.424	**.691**	**.039**
	Aug PRS-P vs grain yld	.166	.380	.621	.075
	Harv PRS-P vs grain yld	.058	.761	.616	.077
Legume	July PRS-P vs grain yld	.004	.983	-.054	.889
	Aug PRS-P vs grain yld	-.001	.997	.031	.936
	Harv PRS-P vs grain yld	-.048	.811	.284	.459

(e) Conclusions:

In the absence of inorganic fertilizers being applied in organically managed cropping systems, nutrient mineralization becomes a more important source of nutrients for crop growth and productivity. However, it does not appear that rates of mineralization are higher in the organic systems compared to the conventional systems, just that there is a higher reliance on mineralized N for growth. Depending on the soil zone, both N and P mineralization rates were higher, lower or not different in the organic soils compared to the conventional soils. The sample size of 3 organic and 1 conventional farm per soil zone (except for only 1 of each in the Gray soil zone) makes it impossible to generalize the results to all farms in a zone, but gives a clear indication that the organically managed soils do not inherently support higher mineralization rates. In the long term this is desirable since it indicates that organic matter resources will not be depleted more rapidly in the organically managed soils than the conventionally managed soils. However, in the short term it means that nutrients can be (and are) limiting in these organically managed soils.

Potential mineralization measurements do not provide any specific information about the organisms or groups of organisms responsible for mineralization. The different direction of the correlations between available N and mineralization for the organic and conventional soils suggests that there are different controls on mineralization in the two systems. The positive correlation in organic soils means that when available N is low, mineralization is low and is probably linked to the overall N status of the soil. When the overall N balance of the soil is low, then the amount of mineralization is similarly low, because of substrate availability. The reverse relationship in the conventional soils indicates that low available N triggers higher mineralization and is probably a feedback mechanism related to the functioning microorganisms. While mineralization rates are generally the same between the two systems there is a suggestion than different organisms are responsible.

Initially our primary interest was in examining P fertility with a secondary interest in N fertility, mainly because legume crops provide an opportunity to introduce N into a soil independently of fertilizer application or mineralization from organic matter. Phosphorus cycling on the other hand occurs strictly in the soil environment and is more

prone to deficient levels developing for crop growth. Both nutrients appear to be limiting for cereal crop productivity in organic systems. Pre-seeding available N levels correlated with mineralization, total yield, total N uptake and PRS-N. Pre-seeding available P levels correlated with mineralization, total P uptake, grain P uptake, and PRS-P. Of all of the availability indices, PRS measurements and nutrient uptake were the most highly correlated, especially in the organic systems. There appears to be a tight link between amounts of N and P in soil solution and N and P uptake into tissues during cereal growth. Yields were always substantially lower on the organic soils compared to the conventional soils indicating that nutrients were limiting to yield in these organically managed soils.

Not surprisingly legume productivity was not linked to N availability indices in either management system. The ability of legumes to biologically fix N uncouples the dependency on soil N levels. Surprisingly, P uptake was similarly uncoupled in the organic system. Legumes formed stronger AMF associations than cereals, and it may be that these associations were responsible for the lack of relationship between soil P indices and growth. The lack of a relationship between PRS-P (and PRS-N) and nutrient uptake in the legumes, indicates that soil nutrient availability was not reflective of plant usage.

Pre-seeding available nutrient levels, in general, were indicative of nutrient mineralization in the organic soils. Low N and P levels reflected low mineralization levels. While it does not provide an estimate of the amount of nutrient that could potentially be released through mineralization, it does appear to be reflective of the overall fertility of the soil.

(f) Acknowledgements:

Information from this project has been presented at a variety of extension meetings and in undergraduate lectures at the University of Saskatchewan. The Saskatchewan Ministry of Agriculture – Agriculture Development Fund and the Strategic Research Program are acknowledged on slides and verbally at each event. Funding for this and other work is greatly appreciated.

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(h) Appendices: none

(i) Other:

Administrative and other aspects

<u>Personnel involved:</u>

Darin Richman	SRP funded technician	20%
Tandra Fraser	Research technician	50%
Mark Cooke	Research technician	50%
Lisa Howse	Summer student (4 mo)	100%
Kendra Purton	Summer student (4 mo)	100%

Presentations at field days, workshops, conferences and publications (numbers of participants)

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Expense Statement

To follow from Financial Services, U. of S.